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IS LITTER DECOMPOSITION RETARDED IN THE PRESENCE OF MYCORRHIZAL ROOTS IN FOREST SOIL?

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Abstract

In an attempt to investigate possible influence by mycorrhiza on microbial activity in soil a decomposition experiment was carried out in four differently treated plots in a Scots pine (*Pinus silvestris*) stand. The highest yearly weight loss was found in the trenched plots where the mineral soil was either dug or untouched. In the trenched plots in which the mineral soil was dug and the root pieces removed the decomposition was significantly slower as it was in the control plots which had the slowest decomposition. This experiment was copied from one carried out earlier (Gadgil and Gadgil, 1975) and gave the same tendency for decomposition. The possible influence on decomposition by mycorrhiza is discussed.

1. Introduction

In a trenching experiment in a poor spruce forest, Romell (1938) noted that within the trenched plots the plant growth increased considerably and was similar to that of fertilized plants. This effect was suggested by him to be caused by increased mineralization due to green manuring from dead roots and a reduced competition from the tree's mycorrhizal fungi.

A recent investigation of this effect was carried out with a different technique in a Monterey pine (*Pinus radiata*) stand (Gadgil and Gadgil, 1975). From this investigation it appeared reasonable to conclude that the presence of mycorrhiza could have caused a decreased decomposition rate of litter even if the mechanism remains to be explained. Two possible explanations were offered by Gadgil and Gadgil, namely that the root's mycorrhiza repress the activity of the litter-decomposing microorganisms by producing antibiotic substances and/or by competition for nutrients.

Ethylene is an important growth-regulating factor for plants (Abeles, 1973) and possibly also for microorganisms (Smith & Cook, 1974). High amounts of ethylene often found in undisturbed ecosystem soils, like a grassland or a forest, have a general regulating effect on the composition of the microflora, for example by repressing growth of pathogenic fungi while this regulation is weakened in disturbed situations (Smith & Cook, 1974). Ethylene can be produced in the soil by roots (Kays *et al.*, 1974), bacteria (Primrose, 1976) and fungi (Ilag and Curtis, 1968). Substantial amounts of ethylene have been detected in the soil investigated at the Swecon site as a result of microbial activity (Lindberg *et al.*, 1980).

The aim of the present study was to test whether the effect seen by Gadgil and Gadgil (1975) could be seen also in a podzol in a Scots pine (*Pinus silvestris*) stand, and if an effect could be explained by a higher ethylene formation in the undisturbed soil.

2. Site description

The 120-130-year-old Scots pine stand (Ih V) studied is located at the SWECON research site, Ivantjärnsheden, Central Sweden ($60^{\circ}49'$N, $16^{\circ}30'$E) at an altitude of 185 m on a flat area of deep glacifluvial sand sediments. The mean annual precipitation in a nearby village is 609 mm (1931-60), and the mean annual temperature $+3.8^{\circ}$C. The length of the vegetation period is about 160 days.

The tree layer is exclusively composed of *Pinus silvestris* and has a density of 393 trees per ha and a height of 17-19 m. *Calluna vulgaris* and *Vaccinium vitis-idaea* form a well-developed field layer, and the bottom layer, completely covering the ground, is mainly composed of the mosses *Pleurozium schreberi* and *Dicranum rugosum* together with *Cladonia* lichens.

The most recent direct effect of forestry practices is a slight thinning in 1960. Further details on vegetation and stand history are given by Bråkenhielm (1975).

The soil profile is an iron podsol with a weakly developed bleached horizon (2-7 cm) and the humus type is a typical mor. A very loose litter layer (A_{00}), with living mosses and lichens interwoven in it, covers a humus layer (A_{01}-A_{02}) of 5-10 cm. The A_{01} (F) and A_{02} (H) horizons are almost indistinguishable from each other. The pH range is 3.9-4.2 in the humus layer and 4.6-4.8 in the upper mineral soil. The parent mineral material as well as the whole soil is considered as very poor in essential nutrients (Bringmark & Petersson, 1975).

3. Materials and methods

3.1 Soil treatments

Twenty plots measuring 1 x 1 m^2 were selected and given treatments A, B, C or D, five plots of each.

Treatment A: The plot was root-isolated with 1 mm thick aluminium sheets down to a depth of 30 cm. The L-layer with lichens was carefully removed. The combined FH-layer and the mineral soil was dug up and root pieces removed with a 5 mm mesh sieve. The mineral soil, FH-layer and the L-layer were carefully replaced.

Treatment B: As A, but cut-off roots were left and the soil was not sieved.

Treatment C: The plot was only root-isolated.

Treatment D. Control

3.2 Decomposition measurements

Pine needle litter was collected and enclosed in litter-bags as described earlier (Berg and Staaf, 1980). Ten litter-bags were placed between the humus layer and the lichens in each plot. 20 litter-bags from each treatment (four from each of the five plots in a treatment) were sampled after one and two years. The litter was dried at 85^{0}C and weighed. Total nitrogen was determined by Kjeldahl digestion.

3.3 Ethylene determination

The measurement was carried out about one month after the plot treatment was ready.

Approximately 300 g of the FH-layer was placed in a 4 l gas-tight exsiccator and incubated at 13^{0}C for 48 and 68 hours, whereafter ethylene formation was determined gas-chromatographically (Granhall & Lundgren, 1971). Five replicate samples from each treatment were analysed.

4. Results

4.1 Decomposition

The weight loss after one year was significantly lower (95 per cent confidence limits) in the control (D) than in treatments with trenching (C) and trenching - digging (B) (Table 1). Treatment "A", where root pieces also were removed, did not cause any further increase in weight loss.
An analysis of total nitrogen content in the litter did not reveal any differences between litter in the different treatments.

In the measurements carried out after two years' incubation it was not possible to determine the weight loss as the forest floor system had collapsed and large amounts of the lichens had turned into slime.

4.2 Organic - chemical

The analysis gave a similar pattern for the four treatments indicating that there were no notable changes in functional groups of microorganisms as a consequence of the rather violent treatments.

4.3 Ethylene formation

The amounts of ethylene formed were insigificant (< 1 pmol C_2H_4 $gdw^{-1}h^{-1}$) in all treatments.

5. Discussion

The tendency found by Gadgil and Gadgil (1975) in their field study was seen also here, in spite of very different forest systems (Table 1). Neither of these field studies necessarily indicate that mycorrhiza should be the factor repressing activity. In the trenching experiment, Romell (1938) concluded that decreased root uptake and green manuring were responsible for the effect. In the trenching experiment he also observed the presence of certain shrub-like plants, indicating nitrate formation.

In the system of Gadgil and Gadgil (1975) there were not such shrubs or even mosses and their treatments "D" (control) and "C" (Table 1) without any digging could be compared to the study by Romell. The fact that the large effect is seen already with root-isolation only, and that treatments like "A" and "B" give only marginal effects, indicates that further experiments to confirm the effect should proceed along other lines. The small extra effects obtained by digging and sieving the soil could be explained by the presentation of new energy to the microorganisms, resulting in a faster mineralization.

At present, at least three possible explanations can be forwarded.

A very possible explanation is that of mineralization and immobilization of nutrients. In all cases (A, B and C) root uptake was excluded which would make more nutrients available for microorganisms, thus allowing a higher turnover. This is seen already in treatment C - similar to Romell's observation. When removing root litter both easily metabolized carbon sources and nutrients in a possibly readily mineralizable form are removed and could cause a lower turnover.

Inhibiting substances have also been proposed as a possible explanation, for example:

a. Inhibiting substances formed by mycorrhizal roots. This explanation could be applicable to treatments "B" and "C" vs control but the significant difference between "A" and "B-C" still remains to be explained.

b. Inhibiting substances such as ethylene which are formed in the soil. In our study, the formation of ethylene was tested for an no differences were seen between treatments, thus reducing the probability of this factor being of importance. High CO_2 concentration also has an activity decreasing effect. CO_2-formation was not investigated in this study, but a treatment would certainly have affected CO_2-formation.

6. Conclusion

Due to very incomplete knowledge about regulating factors in the soil our contribution to this phenomenon must remain a speculation.

We could suggest that the main difference between the control and treatments "C" and "B" is due to lack of competition for nutrients in the absence of living mycorrhizal roots. The removal of roots means a removal of easily degradable organic substance which might possibly have a priming effect on the decomposition of the other litter.

With regard to the many results published by Gadgil and Gadgil (1975) - for example with regard to amounts of fungal mycelium and with regard to their laboratory measurements, it appears reasonable to assume that there is a phenomenon which deserves further investigations. A number of approaches to this problem are suggested below.

As seen from the suggestions we believe that it is important first to certify the effect and then study the mechanism.

6.1.1 Field studies

(i) Decomposition in trenched plots in coniferous forests with high turn--over and no undervegetation, for example, a spruce forest in Southern Sweden.

(ii) Measurements of amounts of litter and humus in old root isolation experiments where a possible effect has been developed for a large number of years. - A coniferous forest without an understorey would be preferable.

(iii) In (i) - (ii) decomposition should be measured as weight loss of the L-layer and the humus layers.

(iv) Nitrogen dynamics should be followed in cases (i) and (ii). Are there any differences in NH_4^+ (and NO_3^-), total nitrogen, and slowly and quickly released nitrogen?

6.1.2 Laboratory studies

(v) The greenhouse study made by Gadgil and Gadgil (1975) should be repeated with the addition that nitrogen is followed closely and budgets made for the treatments. Preferably such measurements should be made with both *Pinus radiata, Pinus silvestris* and *Picea abies*.

Table 1. Decomposition after 1 year's incubation of litter in trenched plots treated to influence mycorrhiza development. Results from a similar investigation are shown for comparison. Standard error within brackets, significant differences indicated by the lines (n=20)[1].

Site	Treatment A (cut, dug, roots removed)	B (cut, dug)	C (cut)	D (control)	Literature reference
Swecon site	Remaining amount (mg/g)				
Scots pine	694 (10.55)	655 (8.93)	660 (8.72)	702 (10.70)	Present paper
(*Pinus silvestris*)	x——	——x	x——	——x	
		x——	——	——x	
	x——	——	——x		
	Remaining amount (kg/m^2)				
Monterey pine (*Pinus radiata*)	2.98	1.95	2.10	4.69	Gadgil & Gadgil (1975)

1. The significance given is that of at least 99.0 confidence interval.

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